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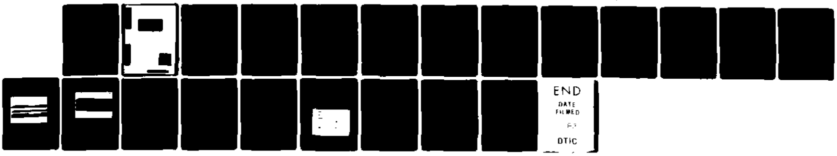

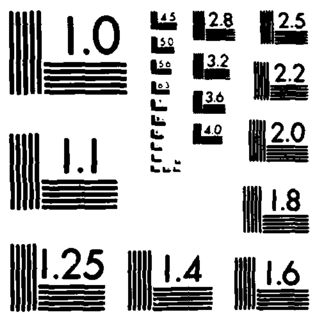

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Defence and Civil Institute of Environmental Medicine

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HUMAN ENGINEERING CONSIDERATIONS
FOR
IMPLEMENTATION OF THE OPERATIONAL INFORMATION SYSTEM
AT THE
WELLAND CANAL TRAFFIC CONTROL CENTRE

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DEPARTMENT OF NATIONAL DEFENCE - CANADA

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ABSTRACT

In response to a request from the St. Lawrence Seaway Authority, DCIEM conducted a study of some human engineering aspects of the implementation of an Operational Information System (OIS) for the Welland Canal Traffic Control Centre. This project is one of the improvements planned by the Authority in order to increase the capacity of the Welland Canal. The study will suggest some human engineering considerations relevant to the introduction of computer equipment for supervisory and traffic control tasks. However, due to the limited duration of this study, only general recommendations are provided.

HUMAN ENGINEERING CONSIDERATIONS FOR IMPLEMENTATION OF THE OPERATIONAL INFORMATION SYSTEM AT THE WELLAND CANAL TRAFFIC CONTROL CENTRE

INTRODUCTION.

In the beginning of 1980 the St. Lawrence Seaway Authority started a program to increase the capacity of the Welland Canal during the 1980's. The program will include the following projects:

1. the design and implementation of a computerized Operational Information System;
2. the design and implementation of a Computer Assisted Traffic Scheduling System;
3. the relocation of the Traffic Control Centre;
4. the upgrading and automation of the overall operational information system (locks and traffic control);
5. the design and implementation of a Traffic Control Training Module.

The main objective of these projects is to improve the accuracy and timeliness of information that is presented to the Traffic Control personnel. More efficient planning of vessel transits is to be achieved by improvements in information quality and the use of a computerized Traffic Scheduling System. This study examines techniques of displaying information in the OIS. General recommendations are given about the use of displays and on the form of the man-computer dialogue.

THE OPERATIONAL INFORMATION SYSTEM.

GENERAL DESCRIPTION.

The objective of the Operational Information System is to provide sufficient information to the Traffic Control personnel to enable them to effectively regulate the traffic in the canal. In addition, the OIS will generate reports for the Welland Canal Traffic Control Centre or other centres such as Ottawa and Cornwall. The OIS will consist of a main computer system, a back up computer system and a large number of video display terminals. The system will process the following information:

1. basic vessel information;
2. vessel movement information;
3. lock operating information;
4. weather information;
5. system status information;
6. control strategy information;
7. other operational information.

This information is used in the Traffic Control Centre by the traffic controllers, the superintendent, the information clerk, the communications clerk and the control officer (fig. 1). The system should be able to display the status of any individual vessel or major part of the canal system at any time. The overall effect of improved information presentation and handling will be a higher passage rate through the Welland Canal.

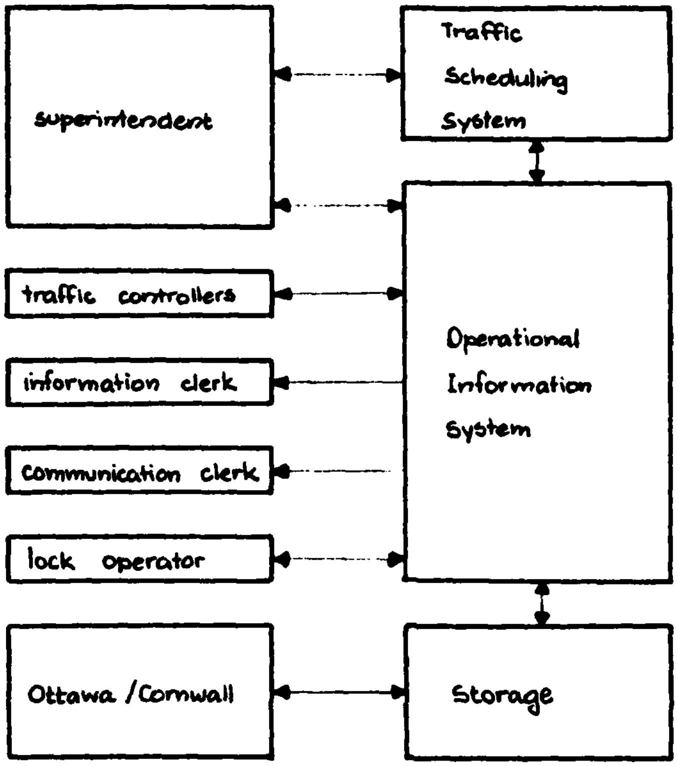

Figure 1. Use of the Operational Information System (OIS)

Primary vessel information is entered into the OIS by one of the lakes traffic controllers. VHF contact is made with the vessels as soon as they enter the control sector at which the vessel reports general information such as name, destination, ETA's etc. After the controller has entered this information into the OIS the data is accessable from the other terminals in the system. Access to this databank of information will enable the controllers to better manage vessel movements.
Control of vessels in the Welland Canal is affected by the canal traffic controller who updates the status and position of the vessels by:

1. verbal radio communication with the vessels;

2. observation by means of closed circuit video cameras mounted near the several locks;

3. input from the lock operators and bridge operators;

4. vessel detectors.

The superintendent needs overall information concerning vessel status and position, especially in the Welland Canal. He is responsible for the planning of the lockage procedures using the Computer Assisted Automatic Traffic Scheduling System. He will enter changes in the lockage procedures into the OIS for the information of the traffic controllers. The communications clerk and information clerk will need access to the databank at all times, with the ability to read data out of the system only and not to change it.
As with any computer system, some provisions must be made to protect the data from system failure. In addition to regular backups being made, some considerations should be given the use of shadow disks. In the event of hardware failure on the main system, the backup (training) computer can assume operation from the shadow disk with no interruption in service and no loss of data.

GENERAL HUMAN ENGINEERING GUIDELINES.

There are some general aspects to be considered in the use of a computer-based information system for the traffic control task. The system, including the computer with its associated terminal equipment, keyboards, printers, etc., can be viewed as an information storage and retrieval system. To be most effective and useful the man-computer system requires more than a good computer system and well-trained operators. Careful attention must be paid to the man-machine interface to ensure rapid and accurate transfer of information from man to machine and machine to man. The equipment, as well as the working environment used, must comply with accepted human factors guidelines. Especially important, however, is the software system and its presentation of information to the operator.

The type of display terminal used by the controllers is a function of many variables. As the task of the Traffic Control personnel is mainly data handling and file handling, the use of standard video display terminals (VDT) may be all that is required. In order to handle other than tabular data, software packages for limited graphic applications are available for use with many VDT's. This would enable graphical presentation of information that is more appropriate to a pictorial representation. Attention to details such as coding of the displayed information will speed up the information transfer to the operator and reduce interpretation errors. Several means of display coding can be used [3]:

1. Alphanumeric coding:
   the language may be coded or abbreviated;

2. Brightness coding or inverse video:

selective brightening or inverse video of parts of the screen can be used to draw attention to particular elements in a display;

3. Shape and size coding:
   the size of the symbols can be varied to indicate differences in importance of information;

4. Flashing or blinking:
   flashing or blinking can indicate urgent or important information.

It is known that colour coding is very helpful to an operator who is monitoring very complex displays, or to operators doing complex search tasks. However, the tasks to be performed on the OIS are such that the added cost and complexity of colour may not be warranted.

The input devices used with a VDT consist of a standard keyboard in combination with multifunction keys or a touch input device. Normally a lightpen cannot be used with VDT's.

Another important factor which affects the man-machine interface is the system software which determines the man-computer dialogue and the method of information display [1][2].

1. Choice of the dialogue type is a fundamental decision. A few examples in increasing degree of complexity are:
   -menu-selection;
   -function keys with command language;
   -user initiated command language;
   -interactive graphics;
   -query language.
   Each of these methods varies in complexity and flexibility of use, and selection must be related to the requirements of the particular tasks. It is recommended that the tasks performed by each traffic controller be assessed to determine the level of complexity that is required.

2. Errors will occur as users input information, and so the system must perform simple validity checks (for example a ship's beam wider than the canal). In addition, error messages must be informative and positive. They should tell the user what to do, rather than what went wrong. The availability of an on-line help facility is very desirable, accessed by activating a 'help' function key. This would provide further explanation of brief error messages, and would list which commands are available as a next step in the procedure.

3. The user should be able to select any display of information at random and should be able to initiate or cancel a command at any time.

4. It would be helpful to the operator if the input procedures were designed to be as simple as possible; for example, the operator must be able to select the next page of information or to scroll information forward or backwards by simply activating a key. Only for specific information requests should several keyboard activations have to be executed.

In addition to the problems of interaction with the computer system, attention should be given to the work environment. Even in a clean and quiet office, a poor workspace layout can increase operator fatigue and errors.
Many factors must be considered including [4]:

1. display angle, keyboard positioning and usable work surface as a function of the operator's posture, reach envelope, etc;

2. effects of illumination on image quality;

3. glare, reflections and adaption;

4. heat, noise, and humidity.

These factors vary with the specific installations and a careful study must be made of each workstation to ensure compliance with good human factors principles.

THE TRAFFIC CONTROLLER.

TASK DESCRIPTION.

The traffic control task is performed by three traffic controllers. The tasks of these controllers are directly related to the area in which they operate (fig. 2).

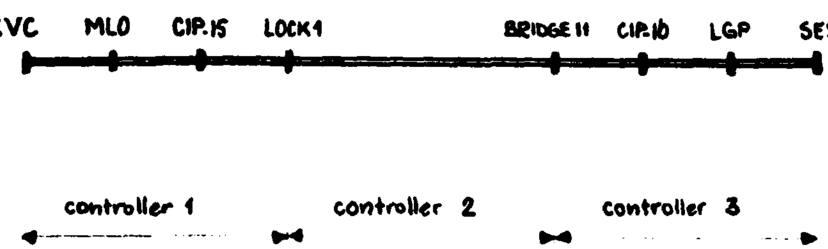

Figure 2. Areas of responsibility of the Traffic Controllers.

The traffic controllers for zones 1 and 3 are mainly concerned with vessels entering or leaving the Welland Canal. They also monitor vessel movements on the lakes and provide the necessary vessel traffic information. The traffic controller for zone 2 is responsible for controlling the vessels safely between lock 1 and bridge 11.
The tasks of these traffic controllers are different and thus their informatio needs are different. They should each receive information which is appropriate to their individual tasks.

The task of the traffic controllers in zones 1 and 3 includes monitoring movements of vessels on Lake Ontario and Lake Erie. These vessels however follow certain predetermined routes. For the controller, the task information needed concerns the number of vessels per route, number of vessels in a particular harbour, and the presence of queues. In the current situation, the positions of the vessels are plotted by hand on a plotboard, representing map information for both the lakes. Magnetic labels representing vessels are moved to the approximate positions of these vessels on the lakes. Each half hour the positions are updated by hand. The geographic information, however, is only partially relevant to the task being performed. This is because the exact positions of the vessels are unknown; what is needed is relative position information rather than exact geographical locations.

An appropriate way of displaying information for the lakes controller could be a list in tabular format, presenting the vessel names, cargo, ETA, etc. It would give the operator a quick overall impression of the number of vessels per route, so that he can predict the presence of vessel concentrations. Special function keys could be used to select a complete list of vessel data per route, or harbour, or arriving vessels could be selected in order of ETA. If data concerning one specific vessel are needed, the complete vessel information can be presented after a keyboard entry of the vessel's name or identification.

The canal traffic controller communicates verbally with the vessels to provide:

1. information to the vessels concerning their order, preparation for entry or exit, and indication of the passing entry manoeuvre;

2. advice on passing or overtaking locations;

3. specific answers to queries.

In order to be able to execute these tasks, the canal traffic controller needs vessel identification and movement information, as well as the status of the various locks. In the current system the vessel's identification and position information is presented on a model board on which wooden models are advanced at a constant speed by means of a spindle. The positions of the models are updated by hand using information from verbal communication and from the lock operators, the bridge operators, or from visual feedback from the CCTV cameras. Separate display boards present information concerning lock status, lock timer, raising or dumping, doors opening or closing, etc. The canal traffic controller may base important decisions on positions of the wooden models, while in reality the model's position does not correspond exactly to the position of the vessels. The system does not have feedback from a tracking device. Moreover, observations of the traffic controllers in the Traffic Control Centre indicated that inaccuracy was introduced when the wooden models were placed on the spindle. Obviously, erroneous location information may lead to inaccurate, or even incorrect, decisions.

EXAMPLES OF POSSIBLE DISPLAY FORMATS.

A suitable method of information presentation for the canal traffic controller is the division of the Welland Canal information into three pages. Page 1 would display information for locks 1,2 and 3, page 2 for lock 4,5 and 6 (flight locks), and page 3 for locks 7 and 8. An example of possible layouts of pages is shown in figures 3 and 4.

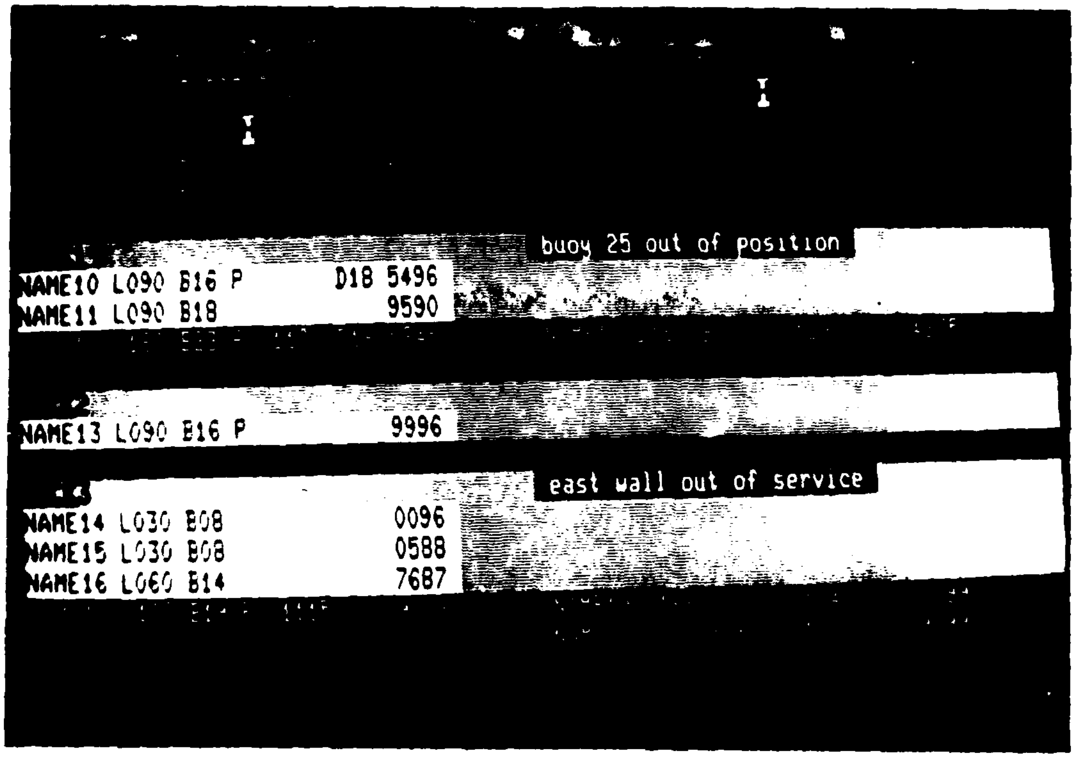

Figure 3. Information concerning lock 1,2 and 3.

Vessel information is presented in tables, the vessel with the earliest ETA being mentioned first, the vessel with the next ETA second, etc, indicating the order in which the vessels will arrive at the next lock. These ETA's are calculated by the OIS. Information on upbound and downbound traffic must be clearly separated, perhaps in separate columns.

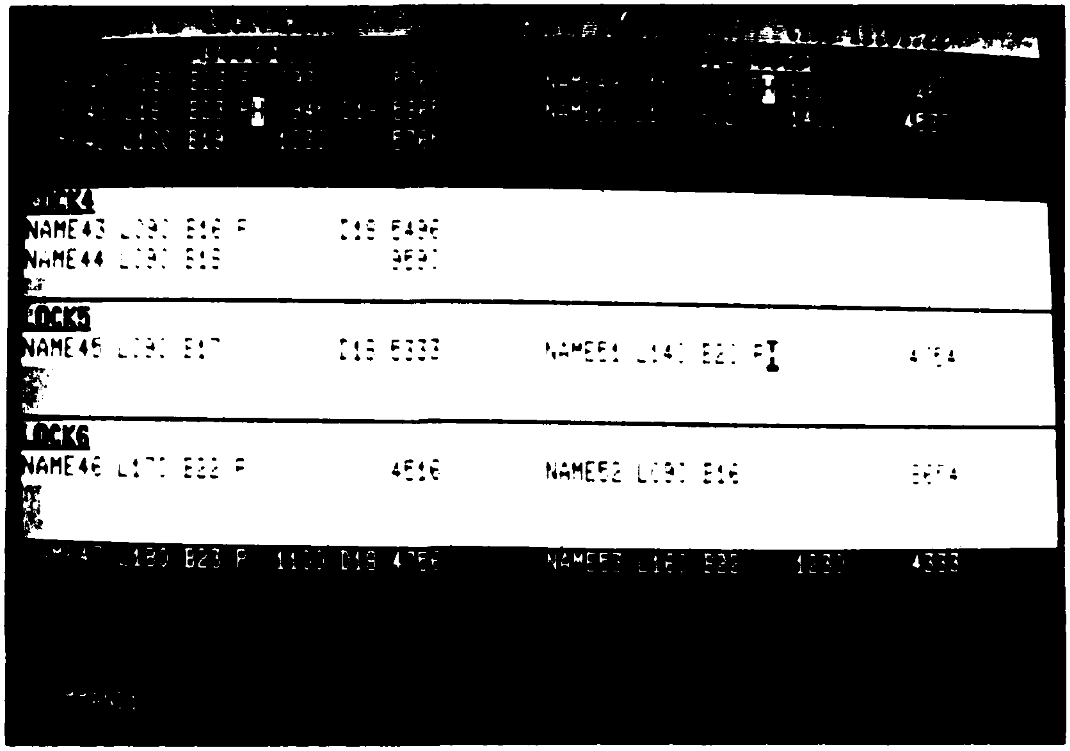

Figure 4. Information concerning lock 4,5 and 6.

Alphanumeric coding can be used to present vessel identification information. Other display codings are available to indicate delays in arrival, need for special manoeuvres, hazardous cargo, system input from the superintendent, etc (coding methods are discussed in section 2.?.). Information concerning vessel movements near the locks is entered into the OIS by the lock operator. If a vessel is entering or leaving the lock, the corresponding label will start blinking. When the vessel has moved into the lock or canal, the label will move to the corresponding position on the screen.

The lakes traffic controller requires information concerning vessels on the lakes and in the Welland Canal. Often it is desirable to have more information available than can conveniently be displayed on one screen. One method of handling this is to use paging. The operator could, for example, have his display broken into several pages. Page 1 could be a display of weather information; page 2, a display of special operational information; page 3, a display of telephone numbers, etc. Each of these pages is clear and uncluttered and contains all information needed for that part of the control task. Page selection can be effected by use of a function key. In this way a complete display can be broken down into several pages that are instantly interchanged as the situation demands.

All these pages of information are generated by the same system. The advantage is that each traffic controller as well as the superintendent, can access any information page at any time, and yet each page is relatively uncluttered. Also, in case of emergency or difficulty, any display can be used to recall any page so that another workstation can take over, or assist, any job function.

Each traffic controller needs display information concerning his area of responsibility. The lakes controller needs a page of information about the entrance of the Welland Canal together with information concerning vessel traffic on the lake. The canal traffic controller, however, is interested in at least two pages of canal traffic information. Also each traffic controller needs a display of general information (weather, navigation restrictions, season information, etc). So, in total, each traffic controller will need three VDT's to display all the required information.

Primary information can be divided into several pages as follows:

1. vessels in Lake Ontario entrance of the Welland Canal (locks 1, 2 and 3);
2. vessels in the Welland Canal (locks 4, 5 and 6);
3. vessels in lake Erie entrance of the Welland Canal (locks 7 and 8);
4. information on vessels in Welland Canal sorted by name;
5. information on vessels in Welland Canal sorted by order;
6. total vessel information in the system sorted by identification;
7. traffic density on Lake Ontario per route;
8. vessels per route on Lake Ontario sorted by name;
9. vessels per route on Lake Ontario sorted by ETA;
10. traffic density on Lake Erie per route;
11. vessels per route on Lake Erie sorted by name;
12. vessels per route on Lake Erie sorted by ETA;
13. lock status information;
14. weather information;
15. general system status information;
16. control strategy information;
17. any other general operational information.

THE SUPERINTENDENT.

In principle, the superintendent will have access to the same OIS information pages as the traffic controller. His task is focussed mainly on planning the transit of the vessels through the locks. To do this he will use the three Welland Canal pages on three different VDT's. He will also use the Computer Assisted Traffic Scheduling System, which will determine the optimal order for the vessels going through the structures and restricted areas. Changes in traffic strategy can be entered into the OIS manually or automatically, making it immediately available for the traffic controllers.

PRESENTATION OF GENERAL INFORMATION.

General information can be used by any operator at any time. There are three categories of general information:

LOCK OPERATING INFORMATION.

Lock operating information comprises frequently changing information like raise, dump, level, lock equipment status, navigation lights, lock approach sign, etc. The lock status information is important to all personnel in the traffic control centre, and should be accessible at any time. It should be presented in analogue form as much as possible on separate pages of a dedicated VDT, as shown in figure 5.

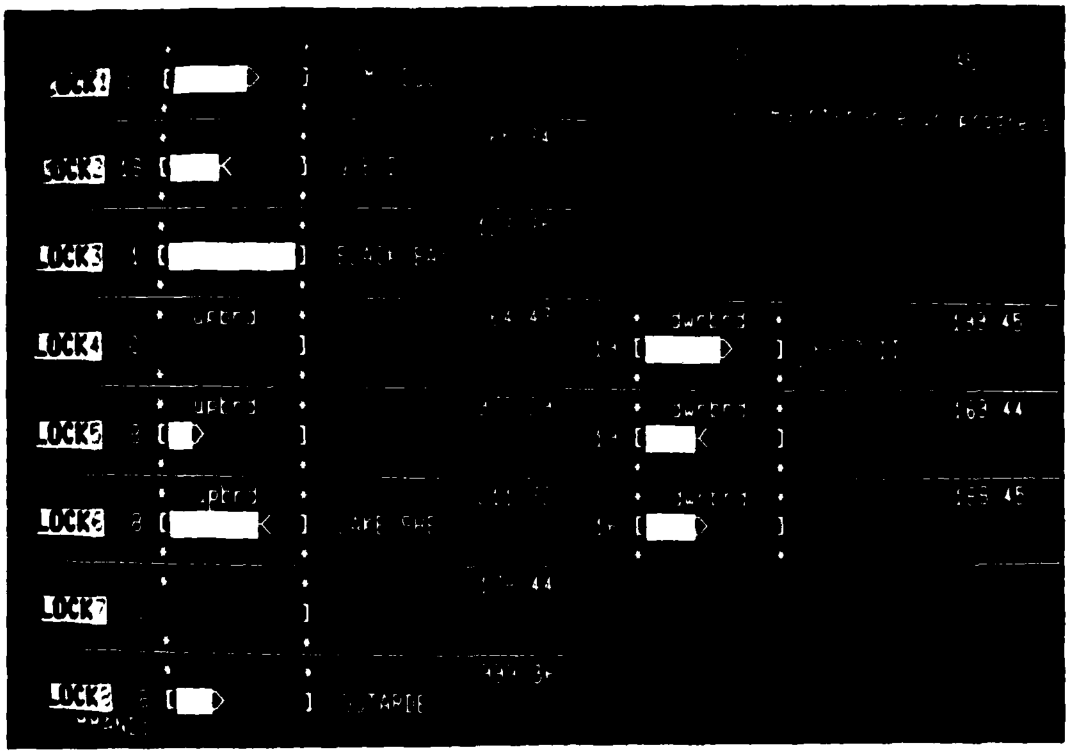

Figure 5. An example of a lock status display.

Figure 5 demonstrates that, under normal conditions, it is possible to present status information for all the locks on one single page. The status of the navigation lights, the water level raising or dumping, and the status of the doors are displayed for each lock. Closed doors are presented by brackets which are blinking when the doors are moving. In addition, names of vessels located in the lock are displayed. The vessel's complete identification information is presented on the Welland Canal pages. It is possible, in an exceptional situation, that there will be too many vessels in the locks to display on one page. In that case the display should scroll up and down automatically.

OTHER OPERATIONAL INFORMATION.

This is relatively slowly changing information, like weather, status (navigation restrictions, walls out of service, etc.), control strategy (lock performance feedback, vessel performance feedback, etc.), or general (wind tables, guard gate navigation lights, close of navigation season information, telephone numbers, etc.). This information is displayed on different pages, which are directly accessible and can be displayed immediately on any VDT.

INFORMATION FROM THE CCTV.

Outside information from CCTV cameras is presented on separate monitors. Presently the operator uses a joystick to pan and zoom the camera. The only visual feedback available is from physical objects in the picture. Since camera orientation is normally either to the north or to the south, so looking up or down the canal, sustained joystick operation is required to rotate through 180 degrees. The provision of pushbuttons to select north and south or any intermediate camera orientation, in addition to joystick control, would reduce the amount of effort handling the camera.

THE COMPUTER ASSISTED TRAINING SYSTEM.

By means of the Computer Assisted Training System, the traffic control personnel can be instructed outside the operational traffic control room. The software for the system will be installed in the back-up computer, and thus not affect the operational computer. It is important that the training equipment have the same layout and responses as the equipment used in the operational traffic control room.

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